THE FIRST TWO YEARS OF HAIL-PREVENTION IN BACS-KISKUN COUNTY

by

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A Bács-Kiskun megyei jégesőelhárítás első két éve. A tanulmány a dél-baranyai kísérleti jellegű jégesőelhárító rendszer tapasztalatainak felhasználásával létesített, *1984* óta működő "Bács-Kiskun megyei Rakétás Jégesőelhárító Egység" első két évének tapasztalatairól számol be. Foglalkozik a védett terület kiválasztásának szempontjaival, a védett terület éghajlati viszonyaival, a jégesők gyakoriságával és területi eloszlásával, a Jégesőelhárító Egység felépítésével, a jégesőelhárítás módszerével és az Egységben folytatott gyakorlatával.

The study reports on the experience of the first two years of the "Bács-Kiskun County Hail-preventing Unit with Rockets", established making use of the experience of south Baranya hail-preventing system of experimental character and operating since *1984*. It deals with the aspects of the selection of the protected area's climatic conditions, the frequency and regional distribution of hails, the structure of the Hail-preventing Unit, the method of hail-supression, and its practice in the Unit.

Introduction

Hail is one of the most dangerous atmospheric phenomena. Year by year it causes considerable damage in agriculture. Agricultural production, by the transformation of its structure, and by its becoming more intensive, is growing more and more sensitive to hail.

Hail-prevention endeavours to bring about changes artificially in the internal microphysical processes of a cloud or a system of clouds, and in the microstructure of the cloud. That essentially means letting artificial ice-nucleis (silver or lead iodide) in large quantities into what is called the thundercloud's (cumulonimbus) accumulation zone (*SULAKVELIDZE*, *1965*), which is of large water concentration and where water is to be found in a super-cooled state.

So the number of the ice-nucleis is increased at least a hundredfold, and by that, the water drops, which have grown supercooled, are forced to freeze away from the natural ice-nucleis. As a result of the intervention, the increase of the natural hailstones is limited; whereby many more but much smaller hailstones come into being. These, while falling, partly or entirely melt in the air-space of positive temperature before dropping onto the surface.

In Hungary it was in *1973* that a government decision was born for the introduction of the protection against hail (*WIRTH*, *1985*). Prior to that, as early as *1961*, the research team of cloud physics was formed which got, as a task, the theoretical preparation and foundation of this practical activity.

In this country the first hail-preventing unit was developed in *Baranya County*, where in *1976* the protection began.

The structure of the "Bács-Kiskun megyei Rakétás Jégesőelhárító Egység" or Bács RJE (Bács-Kiskun County Hail-preventing Unit with Rockets)

After the successful trials of intervention in *Baranya*, a decision was born for the extension of hail-prevention. The choice fell, as quasi the continuation of the *Baranya* protected area, on the southern part of *Bács-Kiskun County*, where grapes, fruits and vegetables - which are sensitive to hail - amount to an important part of agricultural produce (*Hosszuhegy, Baja* and *Bácsalmás Agricultural Combinates*, the district of *Kalocsa*, etc.).

Subsequently to the planning and effectuation, in 1985 began the defence in the *Bács-Kiskun County Hail-preventing Unit with Rockets (Bács RJE)*.

The protected area (*PA*) of the *Bács RJE* is bordered in the west by the Danube, in the south by the *Hungarian-Jugoslav national boundary*, in the east approximately by the line *Csikéria-Kiskunhalas*, and in the north by the line *Kiskunhalas-Császártöltés-Fajsz*. Its area is approximately *5,000* km². The direction centre (*DC*) of the system settled in *Dusnok*, in the north-western tip of the protected area.

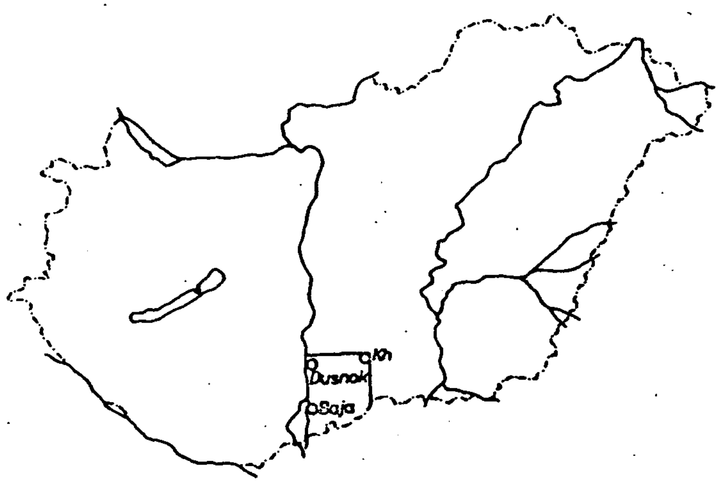

Fig. 1 Situation of the protected area of the Bács-Kiskun County Hail-preventig Unit with Rockets ("Bács-Kiskun megyei Rakétás Jégesőelhárító Egység" or Bács RJE) in Hungary

The determination of the protected area cannot be considered to be exact for several reasons:

- because of safety regulations the major settlements and their immediate environments cannot be defined;
- there are no reliable data relating to how long the nucleation makes its influence felt in the clouds, and in what way this manifests itself in the space.

Placing the direction centre into the north-western corner of the protected area carries several advantages. For example:

- the thunderstorm activity or haily processes, approaching mostly from the west, can be observed well in advance, and thus in the system, preparedness can be ordered in time;
- the area called "dead ground", which is in the immediate vicinity of the radar and has a radius of about *10* km, is confined to the smallest one possible;
- for scanning the air-space of the protected area, you have to move the aerial of the radar in sector only, which means a considerable time-saving.

In the area of the *Bács RJE*, the protection is effected from *18* rocket launching bases. Corresponding with the parameters of the method applied and of the rockets used for the intervention, these bases have been settled so that the regions with a radius of *8 km* considered to be useful should partly overlap each other (*Fig. 2*). This, in principle, makes it possible for us to send reagents over any point of the protected area.

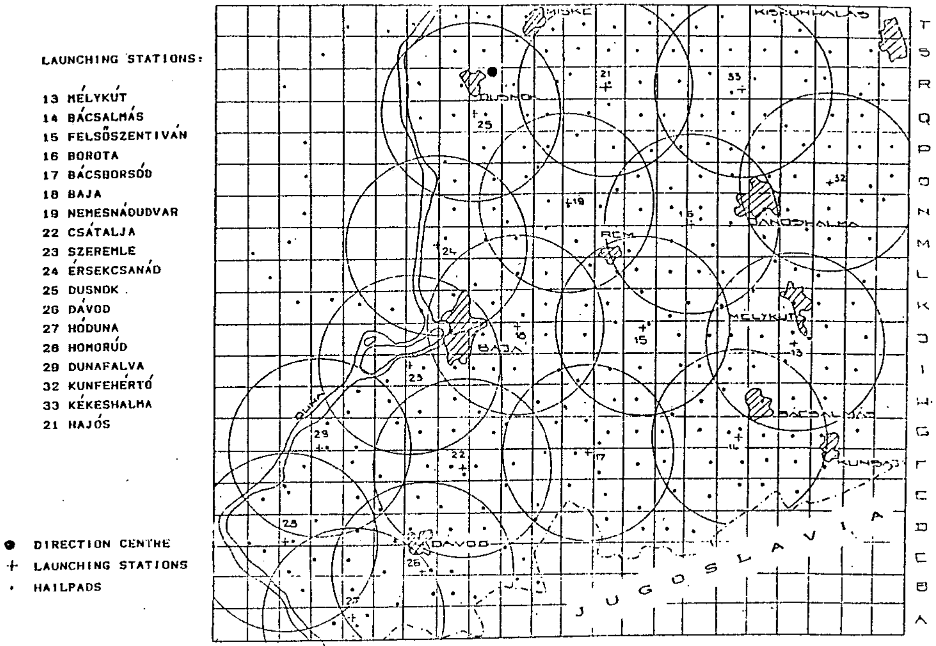

Fig 2 Protected area and networks of launching stations and hail indicators of Bács RJE

Climatic Conditions

Concerning the *Bács RJE*'s area, we only possess informations about the protection season (*1st April - 31st October*) and about as few as *2-3* years. For that very reason, the analysis and judgement of the data partly deviate from the usual points of view. Instead of averageings, the numbers and percentage distributions of cases have been scrutinized. In addition, the practicable aspects of hail-prevention require, too, for the protected area to be considered as a unit (abstractly punctiform).

The *Bács RJE*'s protected area belongs to this country's districts of secondary maximum thunderstorm frequency (*BACSO, 1953*). According to the obervations of many years, the number of the stormy days can be put at *20 - 30* yearly. By contrast, in *1985* in the area of the *Bács RJE* there were *37*, while in *1986* there were *54* days on which it was at at least one station of the system that thunderstorm was reported. The numbers of the thunderstorms were something greater than that; in *1985* the number was *42*, while in *1986* it was *58*. The points of time of the outbreaks of the thunderstorms, according to the ones known from literature, can mainly be dated to the afternoon hours, between *12* and *19* hours (1000-1700 GMT). In addition, the percentage of the late evening and night thunderstorms, too, is considerable, more than *20 %* (*Table 1*).

Also the distribution of hails in space and time is asystematic. Literature (*BACSO, 1953, GOTZ and MESZAROS, 1968*) keeps in mind *1-3* hails a year averagely at every measuring point in this country. On the basis of the *Bács RJE*'s measurements by hail indicators in *1984-1986*, all that is verified (*Fig. 3*). In the three years analysed, the number of the points at which *4*, possibly even *5* hails occured was inconsiderable (*Fig. 3, 1986*). From the measurements carriead out so far it seems that it is the western

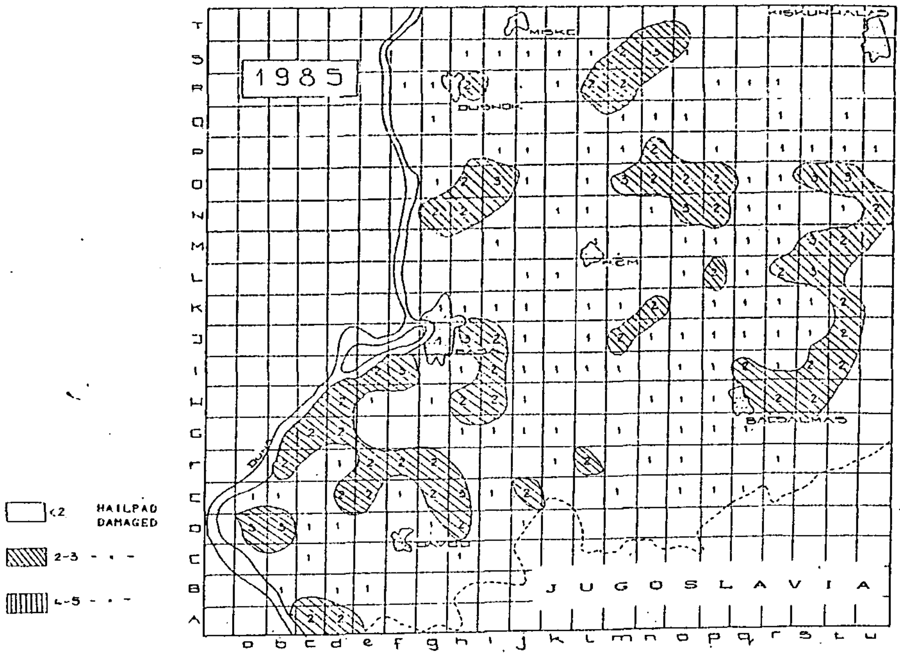

Fig. 3 Numbers of damaged hail indicators in each measuring point

edge of the protected area – first of all, the range of *Baja, Mohács and Sükösd* – as well as its south-eastern part which are most frequently reached by hailstorms. At the same time, in each of the three years id did not hail at all in a considerable part of the protected area.

The observations at the single points do not truly reflect the hail-frequency of an area. Just therefore, it is advisable to extend the investigation of hail-frequency over a major area (*1,000 km²*). According to the Hungarian researches relating to this (*GÖTZ and MESZÁROS, 1968*), in this area of the Great Hungarian Plain, where also the protected area of the *Bács RJE* is to be found, it hails *6-8* times yearly. If, again, the protected area is considered as a unit, and the practicable aspects of hail-prevention are made primary, then the number of hails will be even considerably greater than that. So for instance, in *1984* there were *25*, in *1985* there were *22*, while in *1986* there were *27* days on which it hailed at at least one point of the *Bács RJE*'s protected area (*Table 2*).

Observing the monthly distribution of the hails, it turns out that most haily days occur in *May*, in *28.4 %* of the cases. This is followed by *June* and *July* (*23.0 %* and *21.6 %* respectively), then by *April* (*14.9 %*) and *August* (*8.1 %*) – (*Table 2*). Otherwise, this distribution does not differ essentially from the distribution known from literature (*BÉCSO, 1953*).

The day-time distribution of the beginnings of the hails has been calculated on the basis of the voluntary observers' reports. During three years – *1984, 1985* and *1986* – from the protected area arrived *205* reports of hail altogether (*Table 3*). In *144* cases (*70.0 %*), the hails began between *14* and *19* hours (12-17 GMT). Within that, in most cases (*17.2 %*) between *18* and *19* hours (16-17 GMT). At night and in the morning, between *22* and *13* hours, hails only occur exceptionally (*Table 4*). The day-time distribution made known considerably deviates from those known from literature.

The lengths of time of the hails, too, have been calculated from the voluntary observers' reports. Accordingly, hailing only rarely holds on for more than *5-10* minutes (*Table 5*). Of the *205* reports already mentioned, in *168* cases the duration of hailing, could also be determined; *71* times of these (*42.2 %*), the hailings did not last longer than *5* minutes; however, in as many as *77.9 %* of the cases they were of a stretch of time shorter than *15* minutes. It is noticeable that in *April, May* and *June* the hails are not only more frequent but they last longer as well.

Hail generally comes into being under specific aerosynoptic conditions, to which also contribute the physical and geographical characteristics of the area. In the evolution of these processes, the thermal stratification of the air-space, and the altitudes of the isothermal levels of *0°C*, *-5°C* and *-10°C* determining the condition of hail-formation are of decisive importance. The shaping of the thundery and haily processes as well as of the altitudes of the isothermal levels of *0°C* and *-10°C* in the first four months (*April-July*) of the defence season of the year *1985* are shown by *Fig. 4*. (There was an intervention or there were interventions on days emphasized by dotting.)

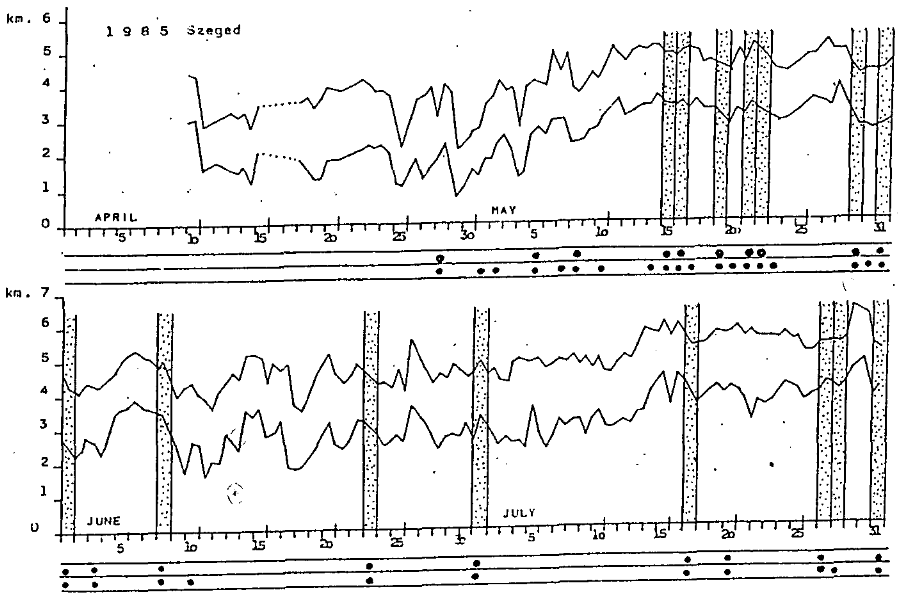

Fig. 4 Changes of the heights of the isotherms of 0°C and -10°C measured at Szeged by radio sondes (at 0000 and 1200 GMT), as well as the distributions of thunderstorms, hails and interventions between 1 April, 1985 and 31 July, 1985

It is generally accepted that the majority of hails are attached to frontal processes; in most cases they occur in a deepenining cyclone, or in the foreside of the trough. A condition of hail danger may also develop differently from that as, and more than once even in a small area. In *Fig. 5* the wether situation of 15th June 1986 and the tunderstorm and hails attaching to that can be seen. Under the influence of a weakening pressure field in the basin of the Mediterranean, there emerged though thunderstorms in Hungary all over the country; hail, however, was reported by not more than two Transdanubian stations (*Sümeg* and *Mohács*). The only meteorological station (the one in *Baja*) to be found in the protected area, also, was

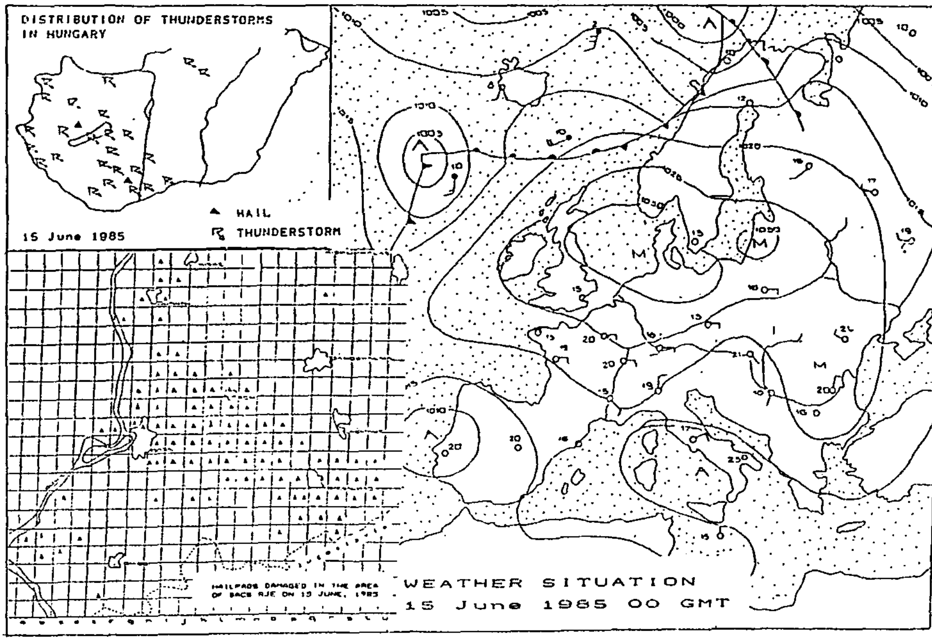

Fig. 5 Weather situation of 15 June, 1986, as well as the distribution of the thunderstorms and hails attaching to it

missed by hail. Nevertheless, almost one-third of the *Bács RJE*'s area was destroyed by hail; and in *1986* the greatest damage done by hail occurred on this day, in an area of some *7,000* hectares.

The method and practice of hail-prevention in the *Bács RJE*

Hail-prevention applies several methods and technologies in these days. In our country - and thus also in the *Bács RJE* - defence goes on by the procedure based on the principle of what is called the "competing embryo-hypothesis", and which has been worked out in the Soviet Union. To send artificial ice nuclei (silver iodide) into the clouds, rockets are used. The major parameters of both the single- and the two-stage type ALAZAN Soviet rockets are contained by *Table 6*.

As conditions of the rise and growth of hail, the following things must be realized in the cloud:

- the velocity of maximum updraught should exceed the value of $10\ ms^{-1}$,
- the maximum velocity of updraught should be in the negative temperature range,
- the temperature of the upper level of convection should be below $-25\,^{\circ}C$,
- the moisture content of the accumulation zone should be able to ensure the moist growth of hailstones.

Under given circumstances, the water supply of the cloud is determined by the velocity of updraught.

The final size of hailstones depends on:

- the velocity of updráught,
- the thickness of the accumulation zone,
- the water supply of the accumulation zone.

The radius of hailstones is given by the relation below:

$$\bar{R}_m = \bar{R}_3^{\,3}\sqrt{\frac{N}{Nm}}$$

where $\bar{R}_3$ = the mean radius of natural hailstones,
N = the concentration of natural ice-formations,
N_m = the concentration of artificial ice-formations.

Thus consequently, if the concentration of natural ice nuclei is artificially increased a hundredfold, then the mean radius of hailstones will decrease to its one-fifth. In *Baranya County*, according to the investigations done in relation to the unidimensional cloud model (*MOLNAR, 1985*), the maximum speeds of updraught reached or exceeded *15* ms^{-1} in all cases on the days when hails developed within the air mass. In *80 %* of the cases, the maximum speeds of updraught reached or exceeded *20* $m\ s^{-1}$; while in *70 %* they fell between *20* and *30* ms^{-1}. At the same time, on the 'not icy ' days they were less than *15* ms^{-1} in one-third of the cases .

The preparation of defence begins by analysing the synoptic situation, and the thermodynamic state of the air-space. For this, thunderstorm forecasts are made twice daily. As auxiliary materials, the following things come into use: surface and contour charts, TEMP telegram (depending on the general circulation, the ascents in *Budapest*, *Szeged*, *Belgrade* or *Zagreb*), GRID + a 12 hours' forecast, as well as the unidimensional cloud model derived from the TEMP. The frequency of radar observations (whether they are made every three hours, or every hour, or continuously) is determined by the information content of the forecast (*Fig. 7*).

By the help of the cloud model, the profile of the speed of vertical updraught expectable in the thounderstorm cloud, the ice and water contents of the cloud, the temperature profile in the cloud, as well as the growth of the hailstones during their rise can be determined. It is in this manner that the range of the thunderstorm cloud between *-5°* and *-10°C*, which must be nucleated during the intervention can be marked out (*Fig. 6*).

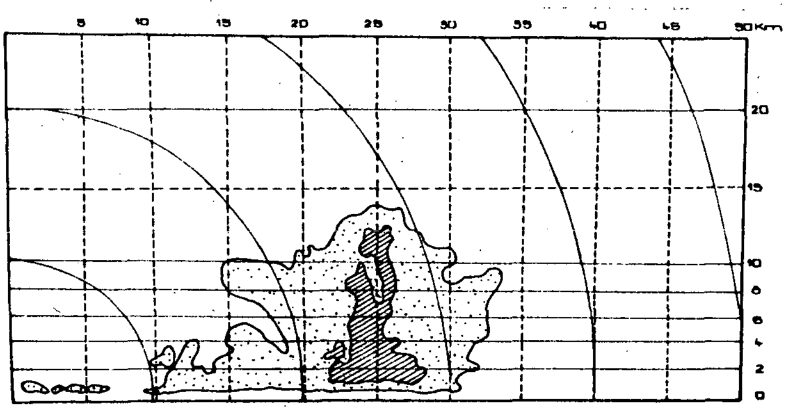

Fig. 6 The (shaded) area to be nucleated of the hail-dangerous thunderstorm cell

As the first step of the intervention (nucleation) procedure, the detection of the air-space is carried out by a Soviet made MRL-5 meteorological radar, deposited in the direction centre, and operating at wave-lengths of *3.2 cm* and *10 cm*. When the intensity of the reflected sign exceeds the threshold of sensitivity of the radio locator, then the radio echo of the sounded object appears, in the form of a bright spot, on the screen of the of the radar. (This is called the reflection zone of the meteorological target.) The intensity of the signal released by the locator and reflected off a cloud, depends on the sizes, physical conditions and shapes of the cloud particals. It is the sizes of a precipitation particle that are the most important factor, for the intensities of the reflections are proportional to the sixth power of the diameters of the particles. This means that if the diameter of the cloud particles increase by an order, then the reflected signals will be a million times intenser.

When the parameters got from the radio locator measurings reach the criterions of the danger of icing determined in the method, the nucleation of the cloud starts (*Fig. 7*).

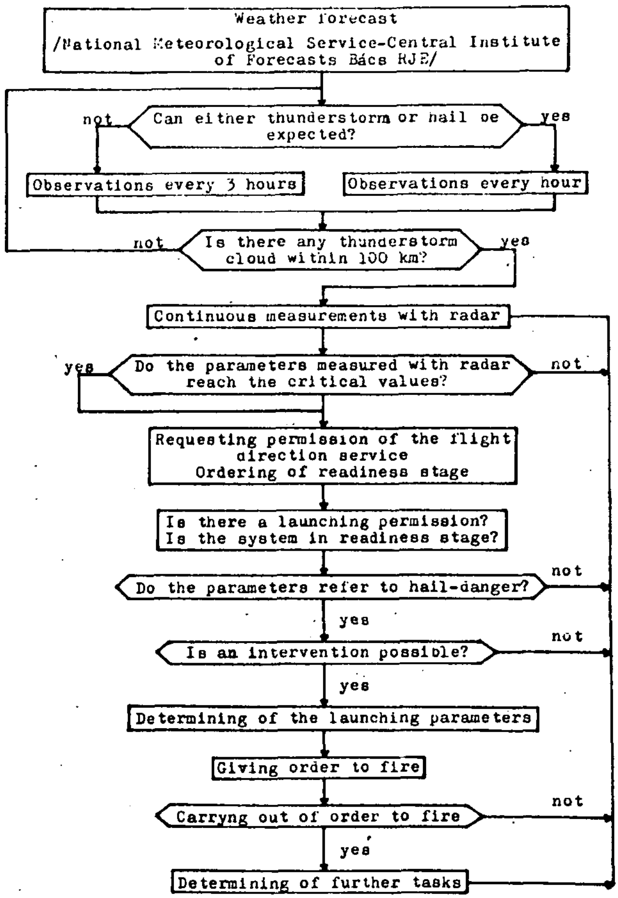

Fig. 7 Process-figure of the intervention procedure

If the nucleation starts too early, there exists a danger that we intervene needlessly, already before the cloud becomes hail-dangerous. If, again, the intervention is late, and the development of hail has already taken place in the cloud; the intervention will be ineffective.

For nucleating the hail-dangerous cells, the direction centre gives, at *V.H.F.*, the rocket launching base most suitable for the intervention an order to fire. The trajectories of the rockets launched in the directions of a triple fan are so determined by the leader of the intervention that the greatest part of the courses of the rockets should fall between the isothermal levels of *-5°C* and *-10°C*, there where hailstone formation is the most intensive. During the reagent dispersion lasting about *35* seconds, *60-120* grams of reagents get into every cubic kilometre of the cloud; ensuring with this the more than a hundredfold ice nucleus concentration postulated by the principle of competition.

In the *1985* season of defence, continuous observations were on *28* days, in the *1986* one on *35*. The number of the days with intervention was considerably smaller, *14* in *1985*, while it was *24* in *1986*. In the two seasons, measurings with radio locators were carried out relating to *1,271* cells altogether. Of these, *166* were nucleated (*Table 7*).

The cells measured have been put among three groups:

- *icy* ones - the ones to that some unambiguous information of ice could be added;
- *not icy* ones - the ones to that no information of ice could be added;
- *uncertain* ones - the ones that had either been measured outside the defended area, and their qualities are not decidable; or had been in the defended area though, but from the available informations of ice it cannot be unambiguously decided from which cells they derive

The ratio of the icy cells to the nucleated ones was *73:57* in *1985*, while it was *80:109* in *1986*. If, in turn, we also consider that it also hailed from at least a part of the cells put into the group of the uncertain ones, then the conclusion can be reached that a considerable part of the hail-dangerous cells received no intervention.

The observation of the regional distribution of the hails

The intensities of hails, their distribution in space and time, as well as the cloud-modificating effect of nucleation can only be valued by an observation network adequate for this. For that, the usual meteorological network is not suitable, is too sparse.

From the *Bács RJE*'s protected area and its immediate vicinity, a multi-channel information system is available.

They are as follows:
- the verbal reports of the rocket launching bases,
- the hail reports of the voluntary observers,
- the network of hailpads,
- the reports about the damage done by hails,
- the measurings with radio locators.

With most information of these supply the written hail reports of the voluntary observers. We come to know from them the place, beginning and duration of a hail, the distribution of the hailstones according to size, the damage caused, etc. (*Tables 3, 4, 5, and 8*). The numbers of hail reports sent in of a hail-day alternated between *1* and *49*; the ones of those sent in from the protected area, between *1* and *36*.

For estimating the areas of thunderstorm cell size, it is the network of hailpads which is suitable. To this end, the protected area of the *Bács RJE* is divided into quadrate areas of *3 km × 3 km* (*Fig. 2*). At some known point of every area of *9* km^2 like this a hailpad is placed.

The hailpads are slabs with a volume of *30 cm × 30 cm × 2 cm*, made from polyurethane foam, on which an aluminium foil of a thickness of $10\mu m$ is sticked. Having been laid on metal plates, the polyurethane slabs are fixed horizontally on a stand. On these deformable plates even hailstones with a diameter smaller than *5 mm* leave their marks. Hailmarks left on a surface of *900 cm²* like that can be counted. We can determine the according-to-size distribution of the hailstones, then from that we can calculate their total mass and kinetic energy (SZEKELY and ZOLTAN, 1984). If we project the data, obtained so, to the damaged area, then we can estimate the degree of the loss of vegetable culture.

In the *Bács RJE*, for determining the real sizes of hailstones we use certified measuring slabs. They are so made that from a definite height, steel balls of a known density but of different diameters are dropped onto a usual hailpad slab. Comparing the impressions, which have come into being so, with the hailstone marks, the diameter of a hailstone can straight be visually determined. The advantage of the procedure, first of all, consists in the fact that it is easy to manage, and is operative.

Setting the hailpads out into the place pointed out in advance (for the most part into the same point) is performed in spring, before the beginning of the season of defence. Their gathering in when finishing the season. In summer, in times of hailing the hailpads are counterchecked (the damaged ones are replaced) according to a programme fixed in advance, or in all cases when a hail-dangerous thunderstorm cell has passed over the area in question. In this way, it is always up-to-date informations that are available in the network of hailpads.

In the defended and neighbouring areas of the *Bács RJE*, the observations were executed in *1984* by *253*, in *1985* by *265* and in *1986* by *304* hailpads.

Table 8 contains the according to size distribution of the hailstones. The first half of the table has been made by processing the hail reports of the voluntary observers. The reports classify the fallen hailstones according to their sizes. Occasionally there may also occur hailstone sizes classable among all the size categories. The second half of the table contains the measurements with the hailpads; within that the monthly or yearly numbers of the damaged hailpads, and the diameter of the biggest hailstone measured in a month or a year.

Damage done by hail. Compensation

In *Bács-Kiskun County*, before the introduction of hail-prevention, averagely *25,971* hectares of the insured areas had been befallen by hails yearly, and the sum of the compensations amounted to *Ft 98,418,000* on a yearly average. This means that to each damaged hectare fell *Ft 3,790*. Of late years, the extent of the areas insured against damage done by hails has increased because the conclusion of the insurance contract is compulsory for the co-operative and state farms in the protected area.

In *1984*, reparable damage, i.e. damage over *5 %* arose on *56,689* hectares in the protected area. The areas which had suffered damage over *5 %* came to *15,725* hectares in *1985*, while in *1986* they came to *17,811* hectares (*Table 9*). In fact, the extent of the areas which had suffered damage by hails must have been essentially larger than that; namely these numbers do not include the areas not insured and the ones which had suffered less damage than *5 %*, as well as the damage which had arisen in small farms. To this we should only like to mention that in *1985* and *1986* the extent of the areas which had suffered less than *5 %* (consequently not reparable) damage was almost just as large as that of the ones which had suffered greater than *5 %* damage.

In *1985* the *Allami Biztosító* (the Hungarian State Insurance Company) paid damages of *106.9 million* forints for the damage done by hails. In *1986* the sum of the indemnities touched *123.9 million* forints.

In the majority of cases, a considerable part of the damage done by hail arises on a few, more than once *on 1-2 days*. So for example, in the later protected area, on one single day, *2 July 1984* reparable damage done by hail arose, totalling *30,018* hectares. That amounts to *54.3 %* of the area which in 1984 suffered reparable damage by hail, and which is almost as great in itself as the areas that suffered reparable damage in the years 1985 and 1986 taken all together. Similarly, on *8* and *23 June 1985*, too, 14,973 hectares were overtaken by reparable damage by hail, what correspond to *51.1 %* of the total damaged area of that year.

Conclusions

In the - short - period analysed, the spatial and temporal distributions of the stormy and haily processes, in many respects agreed, with those known from literature, but, on numerous points, departed from them. It was relatively often that hail occurred in the evening and night hours. The hail prevention system presented conforms to the random distribution of atmospheric phenomena, in the course of its operation, however, the limits of traditional, punctiform observations show themselves.

Although in the area of the *Bács RJE*, between 1984 and 1986, hail fell on *22-27* days annually, nearly half of the damage, which occurred, was each year concentrated on one or two days.

Table I

Points of time of the beginnings of thunderstorms risen in the area of the *Bács RJE* (1985-1986)

Year	Months	Number of days with thunder-storm	Number of thunder-storms altogether	Hours 0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24
	IV	1	1														1										
1	V	18	20	1			1							1	1	3	2	3		4				1	2	1	
9	VI	5	6			1										1	1	1				1				1	
8	VII	5	6	1														2			1				1		1
5	VIII	6	7				1								1		2	1	2								
	IX	2	2																			2					
Sum total		37	42	2	-	1	2	-	-	-	-	-	-	1	2	4	6	7	2	4	1	3	-	1	3	2	1
1	IV	6	6	1									1				1	1			1					1	
9	V	10	10		1								1			2	2		1			2		1			
8	VI	17	21					1		1		1		1		3	3		2	4		2			1	2	
6	VII	12	12		1				1				1				2	2	2	1	1					1	
	VIII	9	9		1								1				1				2	2			1	1	
Sum Total		54	58	1	3	-	-	1	1	1	-	1	4	1	-	5	9	3	5	5	4	6	-	1	2	5	-
1985-1986 Sum total		91	100	3	3	1	2	1	1	1	-	1	4	2	2	9	16	10	7	9	5	9	-	2	5	7	1

Table 2

Distribution of hail-days in the area of the *Bács RJE* (1984-1986)

Year	Apr.	May.	June	July	Aug.	Sept.	Oct.	Sum total
1984	5	7	5	5	2	1	-	25
1985	1	9	4	5	1	1	1	22
1986	5	5	8	6	3	-	-	27
1984-1986	11	21	17	16	6	2	1	74
1984-1986 %	14.9	28.4	23.0	21.6	8.1	2.7	1.3	100.0

Table 3

Distribution of hail reportd received from the network of voluntary observers of the *Bács RJE* (1984-1986)

			Apr.	May	June	July	Aug.	Sept.	Oct.	Total
1984	About how many days have they reported	total	7	12	6	5	4	1	-	35
		from PA	5	6	1	4	2	-	-	18
	Number of reports	total	14	67	45	45	18	6	-	195
		from PA	6	20	17	17	3	-	-	63
1985	About how many days have they reported	total	2	11	3	5	4	2	1	28
		from PA	-	6	3	4	1	1	1	16
	Number of reports	total	3	124	33	37	6	8	1	212
		from PA	-	26	13	9	1	1	1	51
1986	About how many days have they reported	total	6	6	10	2	3	-	-	27
		from PA	4	3	6	2	2	-	-	17
	Number of reports	total	93	53	53	21	13	-	-	233
		from PA	40	19	23	5	4	-	-	205
1984-1986	About how many days have they reported	total	15	29	19	12	11	3	1	90
		from PA	9	15	10	10	5	1	1	51
	Number of reports	total	110	244	131	103	37	14	1	640
		from PA	46	65	53	31	8	1	1	205

PA = Protected Area

Table 4

Day-time distribution of the beginnings of hails fallen in the area of the *Bács RJE*.
(On the basis of the voluntary observers' reports, 1984-1986.)

Hours

Year	Months	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	0-24
1	IV					1							1				1	3								6
9	V										1					11		3	5							20
8	VI														3	4	2	1	1	5	1					17
4	VII															1		5	11							17
	VIII																					1	1	1		3
	Total					1					1		1		3	16	3	12	17	5	1	1	1	1		63
	V													1	2	2	4	12	1		2	1		1		26
1	VI															3	8	1		1						13
9	VII																3			3	2	1				9
8	VIII														1											1
5	IX																			1						1
	X														1											1
	Total													1	4	5	15	13	1	5	4	2		1		51
1	IV											1	1	1			3	3		20	3	4	4			40
9	V														3	6	6	1			2			1		19
8	VI					1		1	2										1	4			13		1	23
6	VII																1	1	3							5
	VIII																1			2					1	4
	Total					1		1	2			1	1	1	3	6	11	5	4	26	5	4	17	1	2	91
1984-1986 Sum total						2		1	2		1	1	2	2	10	27	29	30	22	36	10	7	18	3	2	205
1984-1986 %						1.0		0.5	1.0		0.5	0.5	1.0	1.0	4.9	13.2	14.1	14.5	10.7	17.5	4.9	3.4	8.8	1.5	1.0	100.0

Table 5

Distribution according to duration of hails observed in the area of *Bács RJE*.
(On the basis of the voluntary observers' reports, 1984-1986.)

Length of time (minute)

Month	Year	1- 5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-75	76-90	Hail-reports total
A	1984	3	-	-	-	-	-	-	-	-	-	-	1	-	1	5
p	1985	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
r	1986	20	5	4	-	-	3	-	1	-	-	-	2	-	-	35
	Total	23	5	4	-	-	3	-	1	-	-	-	3	-	1	40
M	1984	7	4	-	3	-	1	-	-	-	-	-	1	1	-	17
a	1985	5	5	3	2	1	2	1	-	-	-	-	-	-	-	19
y	1986	7	3	2	1	1	-	-	-	-	-	-	-	-	-	14
	Total	19	12	5	6	2	3	1	-	-	-	-	1	1	-	50
J	1984	5	3	3	1	-	1	-	-	-	-	-	1	-	-	14
u	1985	3	5	4	-	-	-	-	-	-	-	-	-	-	-	12
n	1986	5	4	4	4	-	-	1	1	-	-	-	-	-	-	19
	Total	13	12	11	5	-	1	1	1	-	-	-	1	-	-	45
J	1984	4	5	3	2	-	1	-	-	-	-	-	-	-	-	15
u	1985	4	2	-	-	-	-	-	-	-	-	-	-	-	-	6
l	1986	3	-	-	1	-	1	-	-	-	-	-	-	-	-	5
	Total	11	7	3	3	-	2	-	-	-	-	-	-	-	-	26
A	1984	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2
u	1985	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
g	1986	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2
	Total	5	-	-	-	-	-	-	-	-	-	-	-	-	-	5
S	1984	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
e	1985	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1
p	1986	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
t	Total	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1
O	1984	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
c	1985	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
t	1986	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
1984-1986 Apr - Oct	Sum total	71	37	23	14	2	10	2	2	-	-	-	5	1	1	168
	%	42.2	22.0	13.7	8.3	1.2	6.0	1.2	1.2	-	-	-	3.0	0.6	0.6	100.0

Table 6

A few characteristic data of the Soviet rockets of ALAZAN type used by the *Bács RJE*

Characteristics	Type of rocket			
	Alazan M	Alazan M-1SzT	Alazan 2M	Alazan 2M-1SzT
Diameter (mm)	82.5	82.5	82.5	82.5
Length (mm)	1296-1312	838-850	1343-1356	884-895
Mass (kg)	9.64	6.54	8.30	6.80
Mass of reagent charge, PbJ_2(kg)	1.12	1.12	1.28	1.28
Maximum flying height, (km)	7.9	4.3	9.08	4.3
Maximum flying range, (km)	9.7	5.1	10.0	4.6
Time of self destroying, (s)	43+4	43+4	47	47
Duration of dispersing, (s)		about 35		
Output of ice nuclei, (number of pieces)	$2.10^{12} - 5.10^{12}$			

Table 7

Number of thunderstorm cells measured by a radio locator and nucleated in 1985-1986

Year	Month	Cells measured by a radar Total	Icy	Non-icy	Dubious	Nucleated	Number of days with intervention	Height of cloud top, km
	Apr.	7	-	5	2	-	-	5.4
1	May	290	52	165	73	42	7	14.0
9	June	107	11	90	6	5	3	13.2
8	July	66	10	44	12	10	4	17.8
5	Aug.	26	-	22	4	-	-	10.0
	Total	496	73	326	97	57	14	17.8
	%	100.0	14.7	65.7	19.6	11.5	X	X
	Apr.	107	22	12	73	14	3	12.2
1	May	207	24	54	129	29	5	12.8
9	June	263	14	40	209	29	6	15.4
8	July	96	15	14	67	26	6	15.0
6	Aug.	102	5	23	74	11	4	12.8
	Total	775	80	143	552	109	24	25.4
	%	100.0	10.3	18.5	71.2	14.1	X	X
1985-1986	total	1271	153	469	649	166	38	17.8
1985-1986	%	100.0	12.0	36.9	51.1	13.1	X	X

Table 8

Report of voluntary observers — Measuring by indicators

Year	Month	Number of reports	Distribution of hailstones according to size (case-number, mm) 0-5	5.1-7.5	7.6-10	10.1-12.5	12.6-15	15.1-20	20.1-25	25<	Diameter of the biggest hailstone (mm)	Number of damaged indicators (piece)	Diameter of the biggest hailstone (mm)
	IV	6	4	-	-	2	-	-	-	-	12.5	21	15.0
1	V	20	10	11	9	6	1	2	-	-	20.0	151	22.5
9	VI	17	9	11	6	3	1	-	-	-	15.0	133	20.0
8	VII	17	4	4	2	4	6	9	11	9	25.0	53	45.0
4	VIII	3	1	1	1	-	-	1	1	-	25.0	40	25.0
	IX	-	-	-	-	-	-	-	-		-	11	15.0
	Total	63	28	27	18	15	8	12	12	9	25.0	409	45.0
	IV	-	-	-	-	-	-	-	-	-	-	7	7.5
1	V	26	15	17	10	2	1	-	-	-	10.0	124	20.0
9	VI	13	5	8	6	5	-	-	-	-	12.5	68	22.5
8	VII	9	6	2	1	1	1	2	1	-	25.0	18	17.5
5	VIII	1	1	-	-	-	-	-	-	-	5.0	-	-
	IX	1	1	-	-	-	-	-	-	-	5.0	-	-
	X	1	1	1	-	-	-	-	-	-	7.5	-	-
	Total	51	29	28	17	8	2	2	1	-	25.0	217	22.5
	IV	40	15	16	17	8	4	2	-	-	20.0	98	22.5
1	V	19	8	7	9	8	-	-	-	-	12.5	65	22.5
9	VI	23	11	13	6	3	4	1	-	-	20.0	123	22.5
8	VII	5	-	-	3	3	1	-	-	-	15.0	35	22.5
6	VIII	4	-	2	2	2	3	2	2	-	25.0	27	20.0
	Total	91	34	38	37	18	12	5	2	-	25.0	348	22.5
1984-1986	Sum total	205	91	93	72	41	22	19	15	9	25.0	974	45.0

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